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CONTROLLER FOR OCCUPANT RESTRAINT SYSTEM

RELATED APPLICATION

5 This application claims priority to provisional application 60/152,418 filed on September 3, 1999.

BACKGROUND OF THE INVENTION

1. Field of the Invention.

10 This invention relates to a unique method and system for optimizing deployment of an occupant restraint system. The occupant restraint system includes a plurality of sensors that provide multiple input signals to a processing unit that has a fuzzy logic control system for processing the multiple input signals to generate multiple output signals that optimize deployment of the occupant restraint system.

2. Related Art.

15 Many vehicles have airbag systems and seat belt mechanisms that are used to restrain occupants within a vehicle under certain deceleration requirements. If the vehicle decelerates suddenly, such as when a collision occurs, occupants will tend to continue to move forward due to inertial effects. An airbag is deployed under these circumstances to decelerate the occupants' impact speed before they
20 contact a vehicle structure, such as a steering wheel or dashboard. Additionally, if the occupant is wearing a seat belt, pretensioner and retractor mechanisms also assist in controlling motion of the occupant during a collision. The deployment of the airbag and the utilization of the seat belt mechanisms decrease the likelihood of serious injury for the occupants.

If vehicle occupants are positioned too close to the airbag or if a child seat is buckled to the seat, it may be desirable to vary the inflation and deflation rates of the airbag or to prohibit deployment of the airbag to prevent injury to the occupant from the impact of the airbag. It may also be desirable to control the seat
5 belt pretensioner and retractor mechanisms to further prevent injury to occupants.

Occupant sensing systems are used to provide information to optimize or suppress deployment of an airbag if an occupant is determined to be too close to the airbag. These systems typically use a single input to a controller to determine whether or not the airbag should be deployed. The input is usually based on
10 measurement of the seat occupant's weight or monitoring of the occupant's position relative to the airbag deployment area. Based on this input, the controller sends an output signal to control airbag inflation or deflation if a collision occurs.

These systems often do not consider other important factors such as child seat usage, seat belt usage, pre-crash vehicle data, crash severity data, braking
15 data, etc. in determining whether or not to deploy the airbag. Further these systems do not utilize multiple outputs to control both the airbag deployment and the seat belt mechanisms to minimize injury to the occupants.

Thus, it is desirable to have an occupant restraint control system that can utilize multiple inputs to provide multiple output signals to optimize deployment of
20 the occupant restraint system including the operation of seat belt pretensioner and retractor mechanisms and the inflation/deflation rates of the airbag. The system should be easy to install and maintain and should also be easily adaptable to any combination of sensors.

SUMMARY OF THE INVENTION

An occupant restraint system includes a plurality of sensors that provide multiple input signals to a processing unit. The processing unit has a fuzzy logic control system that processes the multiple input signals to generate multiple output signals to optimize deployment of the occupant restraint system. The occupant restraint system preferably includes an airbag assembly with an airbag controller for inflating and deflating an airbag and a seat belt assembly having a seat belt pretensioner mechanism and a seat belt retractor mechanism for controlling the movement of an occupant during a collision.

In one disclosed embodiment, the occupant restraint system includes at least one modifier sensor for generating a modifier signal to enable or disable an occupant restraint system, an occupant sensor assembly for generating an occupant signal representing multiple occupant characteristics, and a collision sensor assembly for generating a collision signal representing vehicle collision characteristics. The processing unit receives the input signals including the modifier, occupant, and collision signals and generates at least one output signal based on the input signals that optimizes deployment of the occupant restraint system.

In a preferred embodiment, the at least one modifier sensor can include various combinations of the following sensors: an occupant presence sensor for determining whether an occupant is present within a predetermined area within the vehicle; a child seat sensor for determining whether a child seat is properly positioned within the predetermined area; and a seat belt usage sensor for determining whether a

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occupant weight signal and an occupant proximity signal, and the collision signal comprised of a collision severity signal and a pre-collision signal. In the preferred embodiment, the at least one output signal is comprised of a plurality of output signals. These output signals can be any of various combinations of the following

5 signals: a multi-stage inflation control signal for controlling the profile of the airbag; a variable venting control signal for controlling deflation speed of the airbag; and a retractor control signal for controlling the retraction force of the seat belt retractor mechanism. Further, the processing unit preferably includes a fuzzy logic control system for optimizing the plurality of output signals based on the plurality of input

10 signals.

A method for controlling an occupant restraint system includes the following steps. At least one modifier signal is generated which can enable or disable an occupant restraint system based on satisfaction of a predetermined condition. An occupant signal is generated that represents multiple occupant characteristics and a

15 collision signal is generated that represents vehicle collision characteristics. The modifier, occupant, and collision signals are transmitted as multiple input signals to a processing unit and at least one output signal is generated based on the input signals to optimize deployment of the occupant restraint system.

One advantage of this system is that multiple inputs are used to specifically

20 tailor multiple outputs for controlling the occupant restraint system. All of the inputs are combined and are necessary to produce the required outputs. The application of a fuzzy logic control system to all of these independent and variable inputs produces the proper control signals for the airbag and seat belt restraint systems while optimizing

the total system response in real time. As a result, the tailored response of the occupant restraint system will have adapted to vehicle conditions sensed prior to and during the collision.

These and other features of the present invention can be best understood from
5 the following specification and drawings, the following of which is a brief description.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an environmental view showing a seat occupant and a restraint system.

10 Figure 2 is a perspective view of a seat with a seat belt system.

Figure 3 is a view similar to Figure 1 but showing a child seat.

Figure 4 is a schematic diagram of a control system for the occupant restraint system.

Figure 5 is a schematic diagram of the multiple input and output signals used
15 for optimal deployment of the occupant restraint system.

Figure 6 is a flow chart of the control process for optimizing deployment of the occupant restraint system.

DETAILED DESCRIPTION OF AN EXEMPLARY EMBODIMENT

20 A vehicle is shown generally at 10 in Figure 1 with an occupant 12 seated in a seat having a seat back 14 supported with respect to a seat bottom 16. The vehicle is equipped with an occupant restraint system that includes an airbag system 18 and a seat belt system 20 that are used to restrain occupants 12 within the vehicle 10

under certain predetermined deceleration requirements. If the vehicle decelerates suddenly, such as when a collision occurs, occupants 12 will tend to continue to move forward due to inertial effects. An airbag controller 22 deploys an airbag 24 under predetermined collision circumstances to decelerate the occupants' impact speed before they contact a vehicle structure, such as a steering wheel or dashboard 26.

The seat belt system 20, shown in Figure 2, typically includes a lap belt portion 28 and a harness portion 30 that are fastened with a buckle 32 to secure the occupant 12 in the seat. The seat belt system 20 also includes a pretensioner mechanism 34 that provides a predetermined tension force on the occupant 12 via the harness portion 30 when the seat belt 20 is in the engaged position and a retractor mechanism 36 that retracts the harness portion 30 after the harness 30 has been extended. If an occupant 12 is buckled to the seat the pretensioner 34 and retractor 36 mechanisms also assist in controlling motion of the occupant 12 during a collision. The pretensioner 34 and retractor 36 mechanisms are shown schematically in Figure 2 to indicate that any type of pretensioner 34 or retractor 36 mechanism known in the art can be used. The deployment of the airbag 24 and the utilization of the seat belt mechanisms 34, 36 decrease the likelihood of serious injury for the occupants 12.

A child seat 38 could also be secured to the seat, shown in Figure 3. If the child seat 38 is facing rearward or is improperly positioned on the seat the airbag 24 should not be deployed. However, under certain predetermined conditions when the child seat 38 is facing forward as shown in Figure 3, it may be desirable

Figure 1 consists of 15 small plots arranged in a grid, showing the relationship between various variables and the probability of a child being in the 'No' category of the 'Child in care' variable. The variables on the x-axis include: child's age, child's sex, child's race, child's religion, child's education, child's income, child's employment, child's marital status, child's health status, child's mental health status, child's physical health status, child's social health status, child's family size, child's family income, and child's family structure. The y-axis for all plots is 'Probability of child in care' ranging from 0.0 to 1.0. The plots show various trends, including linear, quadratic, and step-like relationships.

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The system also includes a child seat sensor 48 for determining whether a child seat 38 is properly positioned within a predetermined area. Any type of sensor 48 could be used including optical, contact, or non-contact type sensors for example. The child seat sensor 48 generates a child seat signal 50 that is sent to the CPU 46. The child seat signal 50 will either be a positive signal indicating that the child seat 38 is present and is in a properly installed position, i.e., facing forward, or a negative signal indicating the child seat 38 is not in the predetermined area or is improperly positioned, i.e. facing rearward. As discussed above, the terms "positive" and "negative" do not indicate a mathematical value and are simply descriptive terms to differentiate between two different signal designations. If the child seat 38 is properly positioned, additional input signals will be processed, but if the child seat 38 is properly positioned or is not present, the airbag 24 will not be deployed.

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negative signal indicating the seat belt 20 is disengaged. As discussed above, the terms "positive" and "negative" do not indicate a mathematical value and are simply descriptive terms to differentiate between two different signal designations.

If the seat belt 20 is engaged, additional input signals will be processed. If the
5 seat belt 20 is disengaged additional input signals will be processed but the pretensioner 34 and retractor 36 mechanisms will not be deployed.

The occupant presence 42, child seat 48, and seat belt usage 52 sensors are referred to as modifier sensors because the sensors 42, 48, 52 are on/off type inputs that can enable or disable certain outputs. Thus, the occupant presence 44, child seat
10 50, and seat belt usage 54 signals are referred to as modifier signals. Any combination of the above referenced modifier sensors and signals can be used as inputs to the CPU 46. Optionally, additional modifier sensors could be used to provide additional input to the CPU 46.

The system also includes a weight sensor 56 that generates a weight signal 58
15 representing occupant weight. The weight sensor 56 can be any type of weight measuring sensor assembly known in the art and can include of a plurality of sensors, such as strain gages for example, to measure occupant weight. An occupant proximity sensor 60 generates an occupant proximity signal 62 representing occupant position relative to a deployment area for the airbag 24. Any type of proximity sensor 60 can
20 be used including optical, contact, or non-contact type sensors for example. The weight 56 and proximity 60 sensors are referred to as occupant sensors. These sensors 56, 60 generate an occupant signal, comprised of the weight 58 and proximity 62 signals, that is sent to the CPU 46 as input for determining inflation/deflation rates for

the airbag 24. Additional occupant sensors and occupant signals could also be used to provide additional input information to the CPU 46.

The system includes a collision sensor assembly with a severity sensor assembly 64 that generates a severity signal 66 representing vehicle collision characteristics occurring at the time of or just after collision. These characteristics can include vehicle speed, position, and/or braking data, for example. The system can optionally include a pre-collision sensor assembly 68 for generating a pre-collision signal 70 representing vehicle characteristics occurring just before collision. These characteristics can include vehicle speed, orientation, and/or braking data, for example.

10 The severity 64 and pre-collision 68 sensor assemblies are preferably comprised of multiple sensors, well known in the art, for measuring and monitoring, vehicle speed, braking force, acceleration, deceleration, etc.

Multiple input signals comprised of any of various combinations of the occupant presence 44, child seat 50, seat belt usage 54, occupant weight 58, occupant proximity 62, severity, and/or pre-collision 70 signals are generated and transmitted to the CPU 46. The CPU 46 receives and processes these input signals and generates multiple output signals that optimize control of the occupant restraint system.

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The output signals are comprised of any of various combinations of the following signals. A retractor control signal 72 controls deployment of the seat belt retractor mechanism 36 to reduce forward momentum of the occupant 12. A multi-stage inflation control signal 74 is used to control the inflation profile of the airbag 24. A variable venting control signal 76 is used to control deflation speed of the airbag 24. Another output signal can include a seat belt pretensioner signal 78 that is

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used to control the tension force on the harness portion 30 of the seat belt 20. Thus, the multiple input signals are processed by the CPU 46, which then generates the multiple output signals including the retractor 72, multi-stage inflation 74, variable venting 76, and/or pretensioner 78 control signals. The CPU 46 utilizes a fuzzy logic control system to optimize the plurality of output signals based on the plurality of input signals to provide optimal deployment of the airbag 24 and seat belt mechanisms 34, 36 based on the type of occupant 12, the position of the occupant 12, the proximity of the occupant 12 to the airbag 24, etc.

Fuzzy logic control systems are well known in the art. The fuzzy logic control system encompasses and expands on Boolean logic. In Boolean logic, events are designated with a "1" or "0" value. Thus, there is only a choice of two different values to describe or designate an event. In a fuzzy logic control system all values between "1" and "0" are used, allowing the choice of multiple values to describe or designate an event. Fuzzy logic control systems also allow classification overlapping, which is strictly forbidden in a Boolean system.

In a control application, the fuzzy logic system preferably includes the following features: membership functions, rules, rule evaluation, and defuzzification. Membership functions equate linguistic names to the values between "0" and "1." The rules include "IF/THEN" statements that use predetermined specifications and data to control the system. Rule evaluation involves the process of combining multiple inputs and applying multiple rules. Based on the input values, one or all of the rules can be used to control the system to some degree. During this step of the process, the rule results are distilled into one fuzzy shape. During the defuzzification step, the result is

translated back into a single value that is used to control the airbag and/or seat belt mechanisms.

By utilizing a fuzzy logic control system, deployment of the airbag 24 and/or seat belt mechanisms 34, 36 can be specifically tailored to different occupants 12 based on size, weight, position, etc. As shown in Figure 5 and as discussed above, the occupant presence 42, child seat 48, and seat belt usage 52 sensors are referred to as modifiers 80 because these sensors 42, 48, 52 are on/off type inputs that can enable or disable certain outputs. In addition to these modifiers 80, other sensors 82 could be used to provide additional input to the CPU 46.

Once the modifiers 80 are processed, additional inputs are evaluated. The additional input includes the occupant weight sensor 56, the occupant position sensor 60 for generating an occupant position signal indicating the position and/or proximity of the occupant 12 relative to the airbag deployment area, the collision severity sensor 64 for measuring multiple collision characteristics occurring at the time of or just after collision, and the pre-collision sensor 68 for measuring vehicle characteristics occurring just before collision. In addition to these inputs, other sensors 84 could be used to provide additional input to the CPU 46.

Once the CPU 46 processes the variable data from the occupant weight sensor 56, the occupant position sensor 60, the collision severity sensor 64, and the pre-collision sensor 68, the fuzzy logic control system is used to process the information and to generate the optimal output control decision. Each of the variable data inputs, i.e. the non-modifier inputs, has a descriptive membership function that describes ranges over their respective domain. The fuzzy logic process combines all of the

inputs and control values for the variable outputs. Preferably the outputs include any combination of the multi-stage inflator signal 74, the retractor force signal 72, the pretensioner signal 78 and/or the variable venting signal 76. Additional output signals can also be generated such as a threshold signal 86, for example.

5 The multi-stage inflator signal 74 allows the system to control the airbag's pressure profile. The airbag 24 can be initially inflated from 75% to 100% of the peak pressure. The threshold signal 86 is the first stage of the multi-stage inflator and determines the firing of the first squib. The retractor force signal 72 allows the seat belt 20 to control some of the occupant's forward momentum during the collision, and
10 preferably applies a constant force to provide a smoother transition for the occupant 12. The variable venting signal 76 allows the airbag 24 to deflate at different speeds to control the ridedown of the occupant 12 after airbag deployment. The seat belt pretensioner signal 78 enables the pretensioner 34 via the seat belt usage sensor 52. The other outputs, i.e., the threshold 86, variable venting 76, and multi-stage inflator
15 74 signals preferably have calculated delays 88, associated within them to let the seat belt pretensioner 34 and retractor 36 mechanisms provide the initial control of the occupant's motion.

A flow chart of the control process for optimizing deployment of the occupant restraint system is shown in Figure 6. First the modifiers 80 are processed. The
20 modifiers 80 can be processed in any order. In one embodiment, the first step is determining the occupant presence 90. If the occupant is present, then the next modifier is processed. If the occupant is not present then the airbag 24 is disabled 92. Next, the CPU 46 determines whether there is a child seat 38 present 94. If the child

seat 38 is not present, then the next modifier is processed. If the child seat 38 is present, the CPU 46 determines whether the child seat 38 is properly positioned. If the child seat 38 is facing towards the rear of the vehicle or is otherwise determined to be improperly installed, the airbag 24 is disabled 92. If the child seat 38 is forward facing
5 or otherwise determined to be properly positioned, then the next modifier is processed.

Next, the CPU 46 determines whether or not the seat belt 20 is engaged 96. If the seat belt 20 is disengaged, then the pretensioner 34 and retractor 36 mechanisms are disabled 98. If the seat belt 20 is engaged, then any additional modifiers 80 would be processed. Once all of the modifiers 80 are processed, the variable data is
10 processed 100. The variable data includes the collision severity data 102, pre-collision data 104, occupant weight data 106, and occupant position/proximity data 108, plus any other additional variable data. As discussed in detail above, the CPU 46 utilizes a fuzzy logic control system to analyze the data 110 and based on this analysis generates an output signal to optimize deployment of the occupant restraint system 112.

15 The method for controlling the occupant restraint system includes the following steps. At least one modifier signal is generated to enable or disable an occupant restraint system based on satisfaction of a predetermined condition. For example, the modifier signal can be comprised of a single signal or a plurality of signals comprised of any combination of the following signals: the occupant presence
20 signal 44, the child seat signal 50, or the seat belt usage signal 54. A positive occupant presence signal 44 indicates that the occupant 12 is present in a predetermined area and a negative occupant presence signal 44 indicates that the occupant 12 is not in the predetermined area. A positive child seat signal 50 indicates that the child seat 38 is

properly installed within the predetermined area and a negative child seat signal indicates that the child seat 38 is not present or is improperly installed within the predetermined area. A positive seat belt usage signal 54 indicates that the seat belt 20 is in an engaged position and a negative seat belt usage signal 54 indicates that the seat belt 20 is in a disengaged position.

An occupant signal is generated representing multiple occupant characteristics such occupant weight and proximity. A collision signal is generated representing vehicle collision characteristics such as speed, position, and braking, for example. The modifier, occupant, and collision signals are transmitted as multiple input signals to the processing unit and at least one output signal is generated based on the input signals to optimize deployment of the occupant restraint system. Additional steps include modifying the output signal to disable the occupant restraint system when either the negative occupant presence signal 44, the negative child seat signal 50, or the negative seat belt 54 usage signal is generated and continuing to process the output signal when either the positive occupant presence signal 44, the positive child seat signal 50, or the positive seat belt usage signal 54 is generated.

The output signal is used to control inflation and deflation of the airbag 24 and to control operation of the pretensioner mechanism 34 and retractor mechanism 36. The output signal can control various functions of the airbag 24 and seat belt 20 systems. A multi-stage inflation control signal 74 for controlling the pressure profile of the airbag 24, a variable venting control signal 76 for controlling deflation speed of the airbag 24, and a retractor control signal 72 for controlling the retraction force of the seat belt retractor mechanism 34 are just some of the output signals that can be

generated by the CPU 46.

A fuzzy logic analysis process is used to generate the output signal based on the plurality of input signals. As discussed in detail above, the fuzzy logic analysis process includes the steps of creating membership functions by assigning names to
5 predetermined values within a designated range; designating rules to be applied to the input signals; evaluating the rules and input signals to form an optimal control decision; and translating the optimal control decision into the output signal.

Optionally, the CPU 46 can be programmed with a neural network for learning vehicle characteristics unique to vehicle type. Each vehicle type has different
10 passenger compartment characteristics. For example, sport utility vehicles have larger passenger compartments than compact cars. To incorporate the subject occupant restraint control system into multiple vehicle types without having to re-develop, re-design, and re-program for each vehicle type, further adaptability can be built into the system by using a neural network. The addition of a neural network would create a
15 neuro-fuzzy system that could learn about the specific vehicle type during the developmental stages such as testing. The fuzzy logic analysis process could then be optimized for the specific vehicle type.

Although a preferred embodiment of this invention has been disclosed, it should be understood that a worker of ordinary skill in the art would recognize many
20 modifications come within the scope of this invention. For that reason, the following claims should be studied to determine the true scope and content of this invention.